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Cell-division of the pollen-mother-cell of Cobaea scandens alba

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(WITH PLATE 14)

Spindle formation in the pollen-mother-cells of *Cobaea scandens* Cav. was studied by Lawson* in 1898. The stages represented in his plates extend from the resting pollen-mother-cell to the time of nuclear reorganization after the second division. With reference to the division of the cell the following statements are made (pp. 177 and 178):

> There is no cell-plate formed until after the second division. . . . In fig. 24 we see three daughter-nuclei in the same plane. By means of the continuous fibers and mantle-fibers they are connected with one another. These fibers now occupy almost the entire cell-cavity. Cell-plates are now formed in the usual way. Swellings appear on the connecting fibers; these increase in size, and finally result in forming cell-walls which separate the daughter-cells from one another.

A complete disappearance of the spindle-fibers is shown to take place (*f. 21, 22*) before the beginning of the second division. The four nuclei resulting from the second division are arranged tetrahedrally in the mother-cell. Every one of the twenty-four cells figured shows evidence of a thickening of the mother-wall.

The behavior of the cells in *Cobaea*, as reported by Lawson, resembles in some respects that of the pollen-mother-cells of *Nicotiana Tabacum*, *Primula sinensis*, *Tropaeolum majus*, and certain other dicotyledons in which cell-division was found by C. H. Farr† to be accomplished, not by the formation of a cell-plate,

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* Lawson, A. A. Some observations on the development of the karyokinetic spindle in the pollen-mother-cells of *Cobaea scandens* Cav. Proc. California Acad. Sci. Bot. III. 1: 168–188. *pl. 33–36*. 1898.

† Farr, C. H. Cytokinesis of the pollen-mother-cells of certain dicotyledons. Mem. N. Y. Bot. Gard. 6: 253–317. *pl. 27–29*. 1916.

but by a process which "involves the furrowing of the protoplast in the plane midway between the nuclei."

The reports of earlier investigators indicated that the majority of dicotyledons formed their microspores by quadripartition. Concerning the details of the process the literature is somewhat inconsistent, as the following summary indicates:

Juel (1900) in the study of *Syringa;* Tischler (1906) in *Ribes, Bryonia, Mirabilis,* and *Potentilla;* and Duggar (1899) in *Bignonia,* stated definitely that cell-plates were formed, but they furnished no details of the process and no figures to illustrate it.

Baranetsky (1880) in his study of *Lathyrus, Hesperis,* and *Ipomoea,* was unable to find cell-plates. His figures show an incipient furrowing of the protoplasts, but he made no comment upon this fact.

Rosanoff (1865) in *Acacia;* Ishikawa (1911) in *Dahlia;* Osawa (1913) in *Taraxacum;* Miss Pace (1912) in *Parnassia;* Shoemaker (1905) in *Hamamelis;* Miss Fraser (1914) in *Vicia;* and Beer (1912) in *Crepis,* indicated in their drawings the absence of cell-plates during cell-division. These authors do not discuss the possibility of cell-division by any other process.

Pringsheim (1859) in the study of *Dahlia;* Rosenberg (1907) in *Hieracium;* and Guignard (1897) in *Magnolia,* likened these forms, in their method of division, to other forms in which the process involved had not been clearly established.

Miss Digby (1912) in the study of *Primula,* and Cannon (1903) in cotton, discussed and figured the constriction of the pollen-mother-cells but failed to state whether or not cell-plates were formed.

A difference of opinion arose concerning the process of division in the pollen-mother-cells of *Althaea.* Wimmel (1850) reported cell-plates; von Mohl (1853), a combination of cell-plates and furrowing; and Pringsheim (1854) reported furrowing. The assertions again lack the necessary background of detail.

Gates (1907) showed a cell-plate in a diagram of a pollen-mother-cell of *Oenothera.* It is accompanied by no explanation of the process.

Naegeli (1842) in *Oenothera, Bryonia,* and *Cucurbita Pepo;* Sachs (1872) in *Tropaeolum;* Strasburger (1873) in *Tropaeolum;*

Lawson (1898) in *Cobaea;* Tischler (1906) in *Bryonia* and *Ribes;* the same author (1908) in *Podophyllum;* and Johnson* (1914) in *Peperomia,* indicated by their figures a type of division differing from that in which cell-plates are formed. In every instance, however, the statement was made that cell-plates were formed.

Miss Nichols (1908) in her study of *Sarracenia* reported a process of division by constriction of the protoplast, but gave no figures to support the idea.

Andrews (1901) reported a combination of cell-plates and furrowing in the division of the pollen-mother-cells of *Magnolia.* No details of the process were discussed.

The early studies of Wimmel (1850) upon *Althaea* and of Hofmeister (1867) upon *Passiflora* indicate, in the light of the recent study by C. H. Farr, a grasp of the essentials of the furrowing process. Perhaps the lack of detail in their presentations, followed by the launching of the more carefully established cell-plate theory, accounted for the lack of recognition of furrowing as a distinct type of pollen-mother-cell division. Special mention is also due Cannon and Miss Digby, who discussed and figured constriction furrows but failed to report the absence of cell-plates; to say nothing of the large group of investigators whose figures indicate the absence of a cell-plate, but who do not commit themselves concerning the nature of the division.

Such fragmentary and contradictory evidence, however, had resulted in leaving the general impression that quadripartition in dicotyledons was accompanied by the formation of cell-plates. It remained for the presentation of a more complete series of stages from the dividing pollen-mother-cells of *Nicotiana Tabacum,* as presented in C. H. Farr's paper, to clearly establish the process of quadripartition by furrowing. It is there shown that the nuclei of the pollen-mother-cells enlarge during pre-synapsis and synapsis; that a thickening of the mother wall also begins during synapsis and continues throughout the nuclear divisions; and that no cytoplasmic division occurs after the first nuclear division. During the metaphases of the homoeotypic division the remaining spindle-fibers of the first division entirely disappear. After the four nuclei resulting from the second division have been fully reorganized, they assume a tetrahedral arrangement in the cell, and a spindle is formed between every two nuclei, making a total of six spindles. "These spindles," as Farr states, "are indistinguishable from each other, in other words it is not possible to tell, either from the nuclei or from the spindles, which of the four nuclei are sister nuclei." A migration of the nuclei occurs resulting in their appression to the plasma-membrane. The cell cavity then becomes lobed. This, it is further shown, appears to be "due to furrowing of the plasma-membrane along the plane midway between each pair of nuclei. The first indication of the furrowing is to be found in the flattening of the protoplast on four sides, each of which is parallel to the plane of three nuclei, so that the entire protoplast assumes the form of a tetrahedron, the nuclei lying near the corners." The furrowing of the plasma-membrane and the invagination of the mother wall take place simultaneously. The furrowing, however, progresses more rapidly at some places than at others. C. H. Farr's description continues as follows:

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* Johnson, D. S. Studies of the development of the Piperaceae,—II. The structure and development of *Peperomia hispidula.* Amer. Jour. Bot. **1**: 323–339. *pl. 36–38.* 1914. Other references to the papers here cited are given by C. H. Farr.

> It is evident that if there are four nuclei arranged tetrahedrally and equidistant from each other within a sphere, there will be four points upon the surface of that sphere which are equidistant from each of three of the nuclei. . . . By the transformation of the sphere into a tetrahedron the plasma-membrane has been brought closer to the nuclear-membrane. At these four points above mentioned, on the plasma-membrane, the constriction of the mother-cell continues to proceed more rapidly than elsewhere. . . . These projections, or invaginations, continue to elongate toward the center of the cell, and consequently in the direction of the fourth nucleus, keeping at all times equidistant from the three nuclei. As a result the four projections meet in the center of the tetranucleate cell, and fusion of their tips occurs. . . . Thus there are organized four protoplasmic masses each with a single nucleus and connected with each of the other four by an isthmus of cytoplasm, at first quite broad. . . . Apparently each isthmus constricts independently of the others. . . . Upon the completion of the division each of the four cells is separated from the other three by a lateral wall which is thicker in its periphery and thinner at its center.

The figures of *Cobaea scandens*, drawn by Lawson, show the absence of division of the cell after the first nuclear division; the disappearance of the spindle of the first division before the beginning of the second division; the thickening of the cell wall; the tetrahedral arrangement of the four nuclei; and a furrow-like indentation of the plasma-membrane. These characteristics suggest a type of cytokinesis similar to that of *Nicotiana*. The plant at least presents for study an instance of quadripartition with no conclusive evidence concerning the presence or absence of a cell-plate during the process of division.

MATERIAL AND METHODS

The material for study was collected from plants of *Cobaea scandens alba* growing in the greenhouse of Columbia University. The large size of the pollen-mother-cells made it possible to determine the stages of their development in the fresh mounts. Upon examination it was found that the cells in all of the anthers of the same bud were in approximately the same stage of development. The material for fixation was then selected by examining one anther from the bud and fixing the four remaining anthers of those which were found to be in the desired stages.

Flemming's strong chromic-acetic-osmic fixing solution was used in the preparation of the material. The sections were made 3–5 μ in thickness, and were stained with Flemming's triple stain.

OBSERVATIONS

The mother-cell at the close of the second nuclear division is very nearly spherical in form. The four nuclei are arranged at this stage and through all of the succeeding stages of microspore formation in a tetrahedral manner within the cell. They are ellipsoidal in form. Their diameter immediately after reorganization is about one-seventh of the diameter of the mother-cell, or 6 μ. An enlargement of the nucleus also takes place during the division of the cell, which results in a diameter of about one-fifth of the mother-cell, or 8.4 μ. The chromatin is at first appressed to the nuclear membrane (FIG. 1.). During the later stages of cell-division it is found scattered throughout the nucleus (FIGS. 3, 4, 7). The nuclei contain one or more larger and several smaller nucleoli, which are usually spherical. Occasionally an oval one may be found among the larger nucleoli. In some sections they are seen to be appressed to the nuclear-membrane (FIGS. 1, 2).

The spindles, of which there are six, a spindle connecting every nucleus with every other one, appear to be inflated (FIG. 1). Spindle-fibers may be found to run along apparently the entire distance from one nucleus to another, and they are quite uniform in thickness throughout their length. Continuous fibers at the extreme outer portion of the spindle may sometimes be found appressed to the plasma-membrane at about their middle points. In the center of the cell the outer fibers of the spindles are seen to cross one another, and leave no inter-spindle areas except a small, usually triangular space at the center of the cell, due to the curvature of the fibers (FIG. 1).

The spindle-fibers in the *Cobaea* exhibit a very different behavior during cell-division than do the spindle-fibers of the larch and onion, as shown by Timberlake.* In the pollen-mother-cells of the larch and in the vegetative cells of the onion, whose divisions are accompanied by the formation of a cell-plate, the continuous fibers, after nuclear division, show a thickening at their ends near the nuclei. This apparently marks the beginning of the activity of the fiber, which soon develops a very marked thickening in the equator. These enlargements upon the fibers seem to unite and form a layer throughout the thickness of the original spindle. This is accompanied by a shortening of the fibers. The central fibers then continue to shorten until they finally disappear, having been used up in the formaton of the cell-plate. While these activities of the fibers are going on, there appears, in the onion, a zone of orange-staining material, presumably carbohydrate in nature, the probable function of which is to serve as reserve material for cell-wall formation.

The continuous fibers in *Cobaea*, in some cases, show a certain amount of thickening throughout about two-thirds of their length, but they remain attenuated at their ends (FIGS. 2, 7). Occasionally a fiber may be found to be thickened apparently throughout its length (FIGS. 5, 7, 8). This thickening, however, is almost negligible when compared with that found in cell-plate formation. In no instances were there found, in any spindle-fibers of the *Cobaea*, such localized enlargements as those shown by Timberlake and others to precede the formation of a cell-plate. No shortening or disappearance of the fibers in any other manner could be found. The continuous fibers between the nuclei are apparently unchanged during the succeeding stages of cell-division (FIGS. 2–7). They seem to be some of the last structures in the cytoplasm to be severed before the separation of the daughter-cells (FIGS. 6, 7). Even after this separation finally occurs the halves of these fibers are found to extend from the nuclei to the plasma-membranes of the two microspores separated by the furrows. The behavior of the fibers in connection with the formation of the cell-plate led Timberlake to say, "the whole process seems to indicate a somewhat plastic character of the fiber." The behavior of the fibers of *Cobaea*, as shown by the present study, suggests that such a statement would not apply to them, but that they are more permanent in nature.

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* Timberlake, H. G. The development and function of the cell plate in higher plants. Bot. Gaz. **30**: 73–99, 154–170. *pl. 8, 9.* 1900.

Across the equators of the spindles a less dense region of cytoplasm appears at about the time of thickening of the fibers (FIG. 2). This also is evident during the remaining stages of division (FIGS. 3–7). It is apparently made more conspicuous by a denser area around the nuclei, which does not extend into the equatorial regions. The peripheral cytoplasm is fibrillar in nature. The fibrillae show at first no tendency to radiate from the nuclei (FIG. 1). The beginning of such a radiation can be seen in FIG. 2. This continues until a distinct radiation is found in the stage represented by FIG. 4, and the condition is maintained throughout the succeeding stages of division. Scattered irregularly through the cytoplasm are many spherical, red-stained bodies which vary greatly in size. In FIG. 3 five such bodies are shown, which appear to be arranged along a fiber, but in general they have no definite arrangement with reference to any other structures in the cell.

Very soon after the completion of the second nuclear division the cell-wall becomes thickened to about one-fifteenth of the diameter of the mother-cell. This thickening is approximately uniform over the entire surface of most of the cells examined. The loose arrangement of the cells in the pollen-chamber may account for this uniform enlargement. The intercellular spaces are usually large enough to prevent the touching of the different cells. Occasionally they may be found in groups of two or three with the walls of the different cells appressed. At this early stage in division the cell-wall has reached almost its maximum thickness. Cells were rarely found whose wall-thickness exceeded one-fourteenth to one-thirteenth of the diameter of the mother-cell.

After the completion of the second nuclear division, the most striking change in the pollen-mother-cell is its lobed appearance. Upon the plasma-membrane, midway between the polar regions of the three nuclei, there appear sharp indentations pointing toward the center of the cell. In a section, three of these may be in view. FIG. 2 clearly shows two such indentations. The absence of the third one is due to the plane in which the section is cut. The view of the adjoining spindle shows that it is not a median section, such as we have in the two other spindles. The cell-wall conforms to these indentations and the fibers through which the furrows pass, aside from being separated in the center, are apparently undisturbed by it.

During the succeeding stages of division there appear in some of the sections, first at the periphery of the spindle equators, later at different points in the equators, small masses of material which vary in their staining reactions according to their size. The smaller ones stain very darkly, almost black, with gentian violet (FIG. 3). The larger ones stain the same as the cell-wall, with a narrow, dark-stained layer of material upon the outside, apparently a membrane (FIG. 7). These bodies do not appear in all of the sections, but they occur in short rows directly in front of the furrow tips, as shown before one furrow in FIG. 5. They are not seen at this time either along the centers of the spindles or in the center of the cell. If any such bodies were present, beyond these short rows, they would be clearly visible because of the regions of less dense cytoplasm across the equators of the spindles.

A careful examination of the sections in which these masses of material appear has resulted in the conclusion that they are never upon the spindle-fibers, but that they are between them; and that the spindle-fibers have no direct relation to their formation. They are believed to be sections of the furrows which are cutting into the cytoplasm of the pollen-mother-cell. In a section such as that shown in FIG. 3, for instance, there has been cut a portion from one of the faces of the tetrahedral mother-cell, and in it are median sections of three nuclei. If in the unsectioned mother-cell every one of the spindles is cut by a furrow, it can be seen that in cutting off this portion from the mother-cell, three half-furrows have been removed. If this severed portion is viewed upon the side opposite to the cut surface, there are seen the three lobes of the mother-cell and the three half-furrows meeting at a point equidistant from the centers of the three lobes. These furrows are cutting sharply into the cytoplasm. It has been stated before that the equatorial regions through which these furrows are advancing are composed of very clear cytoplasm. There are then no visible structures in the line of advance of the furrows except the spindle-fibers. An examination of the cut surface of the section will show that the furrows work in between the fibers in their paths, and later surround them. A cross-section of such a furrow would present a wavy appearance upon its advancing edge. The masses of material which appear in the equatorial regions, as shown in FIGS. 3, 5 and 7, are the severed portions of this edge. The smaller portions consist of the plasma-membrane, while the larger portions are of wall material surrounded by plasma-membrane. It may also be observed that these penetrating tips appear first at the peripheral regions of the equators of the spindles. This is what might be expected if the furrow advances uniformly throughout its length.

C. H. Farr found in *Nicotiana* that the furrows advance much more rapidly than elsewhere from the points of intersection of the six furrows. As he states,

> It is thus apparent that these four projections finally meet in the center of the tetranucleate cell, before the furrows have completed the division on the equator of each spindle. . . . . The first indication of the growth of thes eprojections toward the center of the cell is in the straightening of the spindle-fibers. . . . . This straightening results in the fibers pulling away from the center of the mother-cell, leaving a space which is triangular in section, but is really pyramidal, in the center of the cell.

The projections in his plant are also triangular in section and, in his *f. 32*, are shown as they appear during the earlier stages of furrowing.

In the corresponding stages of *Cobaea* no traces of such projections from the intersections of the furrows could be found (FIGS. 3, 4, 5). While in the tobacco the furrows are found to penetrate more deeply at four points, the furrows of *Cobaea* may be conceived of as advancing, in general, more regularly, penetrating only slightly deeper at many points upon their edges. That the appearance of these furrow tips in the sections is due to the planes in which they are cut may be seen from a comparison of FIGS. 4 and 5. These are adjoining sections of the same pollen-mother-cell. FIG. 4 is drawn from a section cut between FIG. 5 and the fourth nucleus of the cell. Fig. 4 is consequently nearer to the furrows which are advancing from the sides of the lobes, nearer to the fourth nucleus. The projections are very distinct in FIG. 4, but they have not advanced far enough into the cytoplasm to be seen in the section from which FIG. 5 is drawn.

In the center of the cell section, FIG. 6, at the point toward which the tips of the three furrows are pointing, is shown the first appearance of that which will develop, at an even later stage, into the central triangular area of wall material. No straightening of the fibers may be observed to precede it. FIG. 7 represents a very late stage in the process of cell-division, in which the central triangular area may be seen. The furrows have pushed through in other places along the equators of the spindles. Some of the fibers in their paths are not yet surrounded, as can be seen from the drawing. These observations show that except for these slight irregularities the advance of the furrows in *Cobaea* is quite uniform, as has been suggested in connection with their appearance first at the outer portions of the spindle equators. This uniform advance accounts for the appearance of the central triangular section of the furrow at a much later stage than it was found to appear in *Nicotiana*. The daughter cells become almost spherical in form before their complete separation (FIG. 7).

DISCUSSION

The pollen-mother-cells of *Cobaea*, then, present another instance in the microspore formation of dicotyledons, in which the cell-plate is not apparent during cytoplasmic division. The process concerned is, in its general characteristics, like that found by C. H. Farr in *Nicotiana* and other dicotyledons. It differs from *Nicotiana*, however, in possessing some cytoplasmic characteristics similar to those observed in the study of cleavage furrows in the fungi. Mention has already been made of the less dense areas in *Cobaea* which appear across the equators of the spindles during the process of furrowing. Now Harper* found in the study of spore formation in *Pilobolus* and *Fuligo* that a differentiation of the cytoplasm might occur during the process of cleavage. He found "hyaline areas" occurring midway between each pair of nuclei. According to his account the cytoplasm appears as if the protoplasmic mass had contracted about each nucleus as a center, thus leaving irregular, furrow-shaped, less dense spaces in the middle region between the two nuclei.

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* Harper, R. A. Cell and nuclear division in *Fuligo varians*. Bot. Gaz. **30**: 217–251. *pl. 14*. 1900.

In *Cobaea* the less dense areas referred to above are practically free from any granular masses, and appear very clear. The term "hyaline areas" has not been used because the discussion and figures by Harper concerning the somewhat similar regions in the dividing cells of the fungi indicate a condition of greater transparency than is evident in *Cobaea*. These areas also do not appear so markedly wedge-shaped as those shown by Harper in *Fuligo* (*f. 8*). They are, however, in general form, not at all unlike that shown by the same author in his *f. 9*. Aside from these differences, the description of the "hyaline areas" in *Fuligo* and *Pilobolus* might be applied directly to the less dense areas in *Cobaea* without any alteration.

The appearance of such cytoplasmic differentiation in these widely separated forms would seem to be of significance in establishing the similarity of the processes concerned in the divisions by furrowing, and would also give strength to the idea that they are worthy of all of the recognition given them by Harper in the fungi. Since these less dense areas may be found to occur in both dicotyledons and fungi, it must be remembered that the conditions under which they are found are quite similar. In all cases they appear in connection with the cytoplasmic division of a multinucleate cell in which cell-plates are not formed. In all instances so far reported they bound off a single nucleus and never a group of nuclei. They are also the early indicators that the process of cleavage will result in uninucleate masses with approximately equal amounts of cytoplasm.

A comparison of the pollen-mother-cells of the two forms with reference to the breadth of the progressing furrow will show that they are much more narrow in *Cobaea* than in *Nicotiana*. A further comparison of the maximum thickening of the cell-walls in the two forms shows that it reaches a thickness of one-tenth of the pollen-mother-cell in *Nicotiana*, while in *Cobaea* it thickens to only one fifteenth of the mother-cell diameter.

If the cell-wall material is colloidal in nature, the degree of its plasticity would be related to the amount of swelling due to imbibition. This suggests a possible relation between the amount of thickening in the wall and the breadth of the furrow. If in a pollen-mother-cell such as that of *Nicotiana* there is an almost negligible degree of resistance of the cell-wall to the forms assumed by the protoplast, as suggested by C. H. Farr, the pollen-mother-cell-wall of *Cobaea*, which thickens less, might be conceived of as producing a greater resistance to the cell within. The relative surface tension of the protoplast, together with the less plastic cell-wall, might prevent the early rounding up of the lobes of the mother-cell of *Cobaea*, and thus decrease the breadth of the furrow.

The conditions reported in the microspore formation of *Drosera*, by Levine,* suggest a further application of this idea. In that case no cell-plates could be determined during the division of the cells, and they did not present the marked characteristics of a process of division by furrowing. Levine states: "if furrows are present in *Drosera* they must be extremely narrow like those shown in the slime moulds by Harper ('00, '14), which proceed from the periphery to the center of the cytoplasm." The cell-wall of the pollen-mother-cell of *Drosera* thickens to only one-twenty-second of the diameter of the protoplast, and if the previous suggestions are assumed, would exert an even greater degree of resistance to the protoplast than that of *Cobaea*. This may perhaps be great enough to account for an extremely narrow furrow. The fact that the pollen-mother-cells do not separate after cell-division is completed, but form a tetrahedral pollen-grain, may also be of significance in this relation.

It has been observed that some forms of amoeba before making contact with a food particle send forth strands of protoplasm, or pseudopodia, and surround the food. A fusion of these pseudopodia at their free ends or edges results in the complete enclosure of the food. In *Cobaea*, as has been previously stated, the advancing tips of the furrows are seen first between the spindle-fibers, and later they appear to surround them. These observations, together with the appearance of the spindle-fibers throughout cell-division and after division is completed, lead to the conclusion that the fibers are first surrounded and then severed. In considering such a progressing furrow with relation to the fibers, the behavior of the amoebae toward their food particles suggests itself as an analogy. The apparently very elastic plasma-membrane plays a prominent part in both instances. In the process of furrowing the spindle-fiber corresponds to the food particle. It does not seem entirely inconceivable that the advancing edge of the furrow, amoeba-like, may approach a fiber to within a certain distance and then send forth projections which first surround it and finally cause it to separate at its middle point.

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* Levine, M. Somatic and reduction divisions in certain species of *Drosera*. N. Y. Bot. Gar. Mem. **6**: 127–147. *pl. 16–19.* 1916.

The cleavage in *Cobaea*, as has been shown, is directed with reference to the distribution of the nuclei. It seems quite possible, as was suggested by Harper for *Fuligo* and *Pilobolus*, that the nuclei may control the orientation of the furrows, and that the formation of the less dense zones in the cytoplasm is a visible expression of the activity of the nuclei. If to these assumptions are added the suggestions of C. H. Farr, concerning the diffusion of soluble ions from the nuclei along the paths of the fibers, a possible explanation for an amoeboid activity suggests itself. If the fibers mark the paths of diffusion, the compounds formed by the meeting ions would be most concentrated around the fibers in the exact equatorial planes. It does not then seem unthinkable that in these regions of highest concentration the substances may be in the necessary condition to contribute to the development of the plasma-membrane, and that in this manner they determine the position and direction of the penetrating furrows.

To Dr. R. A. Harper I wish to express my appreciation for advice and inspiration during the progress of this study.

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Explanation of plate 14

The figures were drawn with a Spencer 1.8 objective and ocular 4, with a tube length of 170 mm. The magnification is about 1,971 diameters.

FIG. 1. Mother-cell after second nuclear division. Nuclei are organized, spindles inflated, and wall thickened.

FIG. 2. An early stage in the furrowing process, showing thickened fibers and the first appearance of less dense areas.

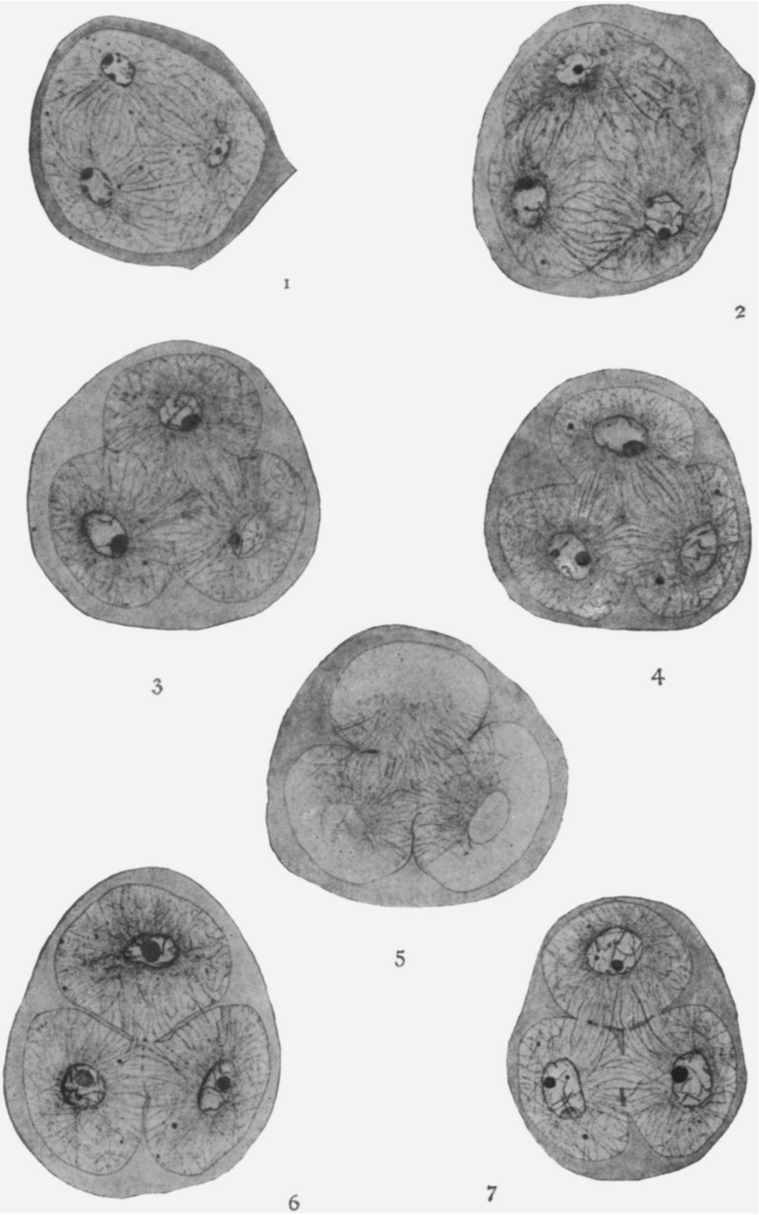
FIG. 3. Furrows penetrating deeper, fibers undisturbed in position, and tips of furrows between fibers.

FIG. 4. A section with deeper furrows, showing no penetrating tips in the less dense areas.

FIG. 5. Another section from the cell represented in FIG. 4, between that section and the fourth nucleus, showing penetrating tips of furrows between the fibers.

FIG. 6. Narrow continuous furrows, tips of furrows, and the beginning of a central triangular area.

FIG. 7. Late stage in division, showing continuous fibers, surrounded fibers, central triangular area, and the rounding up of the daughter-cells.



FARR: POLLEN-MOTHER-CELL OF COBAEA